Student Name: _____

CE 418.3 - Design in Reinforced Concrete

FINAL EXAMINATION

December 10, 2003

Time Allowed: 3 Hours

Professor: B. Sparling

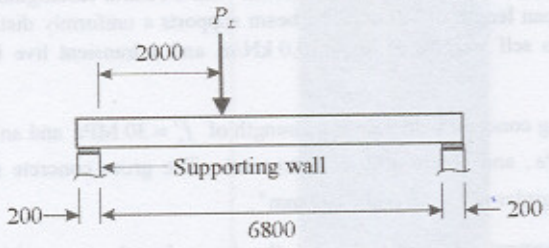
Notes:
- CPCA Concrete Design Handbook may be used
- Closed book examination; Calculators may be used
- The value of each question is provided along the left margin
- Supplemental material is provided at the end of the exam (i.e. formulas)
- Show all your work, including all formulas and calculations
- **Hand in your examination sheets** along with the answer booklet.

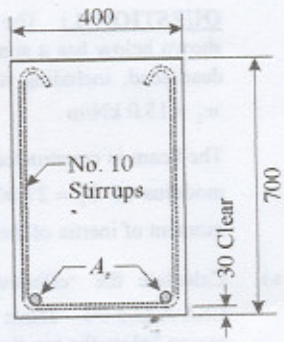
MARKS

QUESTION 1: The reinforced concrete beam shown below is simply supported on two 200 mm wide walls. The beam is constructed using concrete with $f'_c = 35$ MPa and Grade 400 reinforcement. The beam supports a single concentrated live load with a specified magnitude of $P_L = 275$ kN that is applied 2.0 m from the inside face of the left support, as shown on the sketch.

13 **a)** Select the main tensile reinforcement A_s for the beam in accordance with the requirements of CSA-A23.3-94. Design the beam to be singly reinforced and use the same tensile reinforcement throughout the beam's length. Use the normalised design parameters ρ and K_r along with the appropriate design aids in the CPCA Handbook to assist in your selection.

15 **b)** Draw a diagram of the design shear that must be resisted by the beam. Also, determine the required stirrup spacing at exactly 1.25 m from the inside face of the left support. Use the Simplified Method given in Clause 11.3 and satisfy all relevant provisions of CSA A23.3-94.



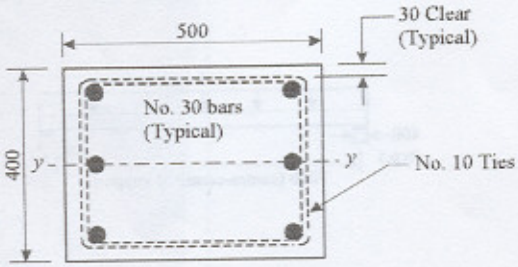


Beam Cross-Section

QUESTION 2: The column shown below is constructed using concrete with $f'_c = 40$ MPa and Grade 400 reinforcement. In addition to an axial load P_f, the column is subjected to a bending moment M_f applied about the *y-y* axis. Use the CPCA Design Handbook **column interaction diagrams** to answer of the following.

8 **a)** Estimate the moment resistance M_r for the column if the applied axial force is $P_f = 3{,}600$ kN.

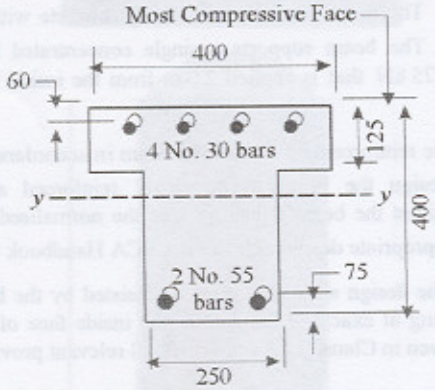
6 **b)** Using the CPCA column interaction diagrams, estimate the axial capacity (P_r) of this column at a **balanced** failure condition.



QUESTION 3: The T-shaped shaped column shown below is constructed using concrete with $f'_c = 30$ MPa ($\alpha_1 = 0.805$ and $\beta_1 = 0.895$) and Grade 400 reinforcement. Assume all bending occurs about the *y-y* bending axis such that the top face experiences the highest level of compressive stress. The plastic centroid of the section is located a distance of 209.0 mm below the top edge (most compressive face) of the column.

15 **a)** Using the basic principles of force equilibrium and strain compatibility, calculate the factored axial load and moment resistance of the column for the condition when the 2 No. 55 bars near the bottom face experience a stress of $f_s = 0.40\, f_y$ **in compression**.

12 **b)** Calculate the factored moment resistance for bending about the *y-y* axis with the top face in compression when there is **no axial load** acting on the column. **Hints:** Assume that all the steel yields and verify this assumption. Also, assume the compression stress block extends into the 250mm wide web region below the bottom of the top flange.



QUESTION 4 : The reinforced concrete box girder (beam with a central rectangular void) shown below has a simple span length of 7.0 m. The beam supports a uniformly distributed dead load, including its own self weight, of $w_D = 10.0$ kN/m and a transient live load of $w_L = 15.0$ kN/m.

The beam is constructed using concrete with a design strength of $f'_c = 30$ MPa and an elastic modulus of $E_c = 27{,}000$ MPa, and Grade 400 reinforcement. The gross concrete section moment of inertia of the box girder is $I_g = 9.634 \times 10^9$ mm^4.

15 **a)** Calculate the "effective" moment of inertia I_e for the beam based on provisions in CSA A23.3-94. **Hint:** The centroidal axis for the cracked section is located in the web region below the top flange (i.e. $c > 120$ mm).

10 **b)** If the allowable midspan deflection in the beam is defined as $\Delta_{all} \le L/300$ to limit the **total visible sag** (deflection) of the beam, check the adequacy of the beam for the given loading conditions. If you were unable to complete Part (a), assume an effective moment of inertia of $I_e = 6.0 \times 10^9$ mm^4 to answer Part (b). The midspan deflection for a simply supported beam subjected to a uniformly distributed load is $\Delta = 5\, w\, L^4 / (384\, E\, I)$.